Resource Pooling and the Trilogy Project

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(with thanks to Mark Handley, Damon Wischik and Marcelo Bagnulo)

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Develop a **unified control architecture for the Future Internet** that can adapt in a scalable, dynamic and robust manner to local operational and business requirements.

Develop and evaluate **new technical solutions for key Internet control elements**: reachability & resource control.

Assess **commercial and social control aspects** of our architecture & technical solutions, including internal & external strategic evaluation.

Funded by the EU under FP7 for 3 years (2008-10)

**Total volume**: 9.15M€
**EU**: 5.82M€

~60 person-years total

[http://www.trilogy-project.eu/](http://www.trilogy-project.eu/)
The architectural requirements have changed

we need a more robust Internet than what we can get from simply making better components

traditional routing can’t solve this in a scalable way

applications are becoming more demanding (VoIP, TV, Games)

most of the end-systems will be mobile, with multiple radios that can be used simultaneously
Resource pooling

make the resources of a network behave like a single, pooled resource
the aim is to increase reliability, flexibility and efficiency
the method is to build mechanisms for shifting load between the various parts of the network on the fly
Resource pooling is not new...

Routing
BGP traffic engineering
- slow, manual process to pool resources across peering links
OSPF/MPLS traffic engineering
- slow, mostly manual process to pool resources across internal ISP links
BT, AT&T and others
- dynamic alternative routing

Elsewhere
multi-homing
- pool reliability & capacity
Google, Akamai, CDNs
- pool reliability & bandwidth
BitTorrent
- pool capacity & reliability

Theoretical foundations
Kelly and Voice
Key, Massoulié and Towsley
Resource pooling for the Internet

**multipath**
the only real way to get robustness is redundancy

**multihoming** – via multiple IP addresses for a system
allows to still aggregate routing information

**mobility** – via adding and removing addresses to a system
no need to involve the routing system
(or use non-aggregatable addresses or identifiers)
Approach

multipath-capable transport layers
use multiple subflows within one transport connection
control perform congestion control for each subflow independently
effect: traffic automatically moves to the less congested paths
note: the involvement of congestion control is crucial
    link the back-off parameters for stability and fairness (Kelly/Voice)
you can’t solve this problem at the IP layer alone (no feedback)
this approach moves some of the stresses out of the routing system
    might be able to converge slowly and no-one cares
(eventually, the routing system should expose in-network multipath availability, so single-homed end systems benefit, too)
Multipath transport

Multipath transport allows multiple paths to be treated as a single pooled resource both in terms of robustness and bandwidth. Traffic moves away from congested paths naturally. Larger bursts can be accommodated, leading to better performance and fault tolerance.
Resource pooling allows a wider range of traffic matrices.
Multipath traffic engineering

Balancing across links of dissimilar **speed**

Balancing across links of dissimilar **cost**

Add congestion marking

$$$

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End-systems can optimize globally (often ISPs cannot)
Where are we today?

good theoretical understanding of the issues (past work by others)
   Kelly and Voice; Key, Massoulié and Towsley

Trilogy is working on the details for TCP & BGP
   how well does this work in practice?
   are there cases where multipath does worse?
   how much of the traffic engineering problems does this solve?
   how much remains to be done in routing?
   how to manage such dynamic networks?

(Trilogy is also investigating other topics)
Next Steps: IETF

Multipath TCP (MPTCP) BOF

proposed for IETF-75 in Stockholm, Sweden (approval pending)

mailing list: multipathtcp@ietf.org

related Internet Drafts

draft-ford-mptcp-multiaddressed ("2-ended variant")
draft-van-beijnum-1e-mp-tcp ("1-ended variant")
Next Steps: Keio University

Michio Honda worked in Trilogy during his internship at Nokia. There is interest from both sides to continue this collaboration. Trilogy and Keio are investigating how an ongoing collaboration could be formalized (NDA, etc.)